Geophysical Research Abstracts
Vol. 18, EGU2016-14485-1, 2016
EGU General Assembly 2016

A laboratory apparatus for forced-oscillation experiments on partially saturated rocks

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Seismic wave attenuation in partially saturated reservoir rocks is influenced by the physical properties of the porous rock and of the inherent pore fluids, including their local saturation state. Therefore, wave attenuation, when studied over a range of frequencies, can be useful to obtain valuable information on the morphology of partially saturated rocks. Quantitative estimates for pore-fluid content and saturation degree as well as fracture density are crucial for a substantial characterization of geothermal reservoirs and monitoring of processes in subsurface fluid-rock systems. Reservoir rocks, such as sandstones, can show heterogeneities of various sizes, starting from micro-cracks on the grain or micrometer scale to faults with several kilometers in length. Solid and fluid heterogeneities may lead to a patch-wise saturation state on the mesoscopic scale, i.e. the characteristic length scale of the patches is much larger than the dominant grain or pore size. The length scales of heterogeneities affect the characteristics of seismic attenuation. Studying this effect is important for the interpretation of seismic data, as obtained for geothermal reservoirs. Thus, we developed a new experimental setup to measure the effective hydro-mechanical properties of partially and fully saturated rock samples under realistic reservoir stress states in the seismic frequency range. This forced-oscillation apparatus is suitable for cylindrical rock samples with a diameter of 30 mm and a length of 75 mm. It is composed of a high-pressure triaxial cell which permits multistep in- and outflow of two different pore fluids under in situ pressure conditions, and a dynamic excitation device. This preloaded piezoelectric actuator with DMS-position sensor can generate a sinusoidal axial displacement that subjects the triaxially loaded sample to an additional harmonic stress with a frequency up to 1 kHz. The applied force is measured externally as well as inside the triaxial cell by a piezoelectric force sensor and a capacitive sensor, respectively. To calculate the effective mechanical properties of the rock sample, its displacement is recorded by two high-resolution capacitive sensors. The gained time- and frequency-dependent material parameters will contribute to a substantial interpretation of attenuation characteristics with respect to the heterogeneity of rocks.